

Calibration and Verification of Three Computer Seasonal Forecast Models

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CFSv2 Evaluation Workshop

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Riverdale, MD



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Region selection

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Model selection

Model	ECMWF	CFSv1	CFSv2
Variable	Temperature		
Forecast	Probability		
	Precipitation		Anomaly

Climatology selection (note)

1982-2009 **2000-2009**

Month selection

← Forecast for →

MAY 2012 JUN 2012 JUL 2012 AUG 2012 SEP 2012 OCT 2012

[Reset](#)

↑
Forecast
made

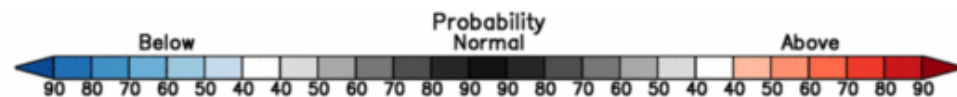
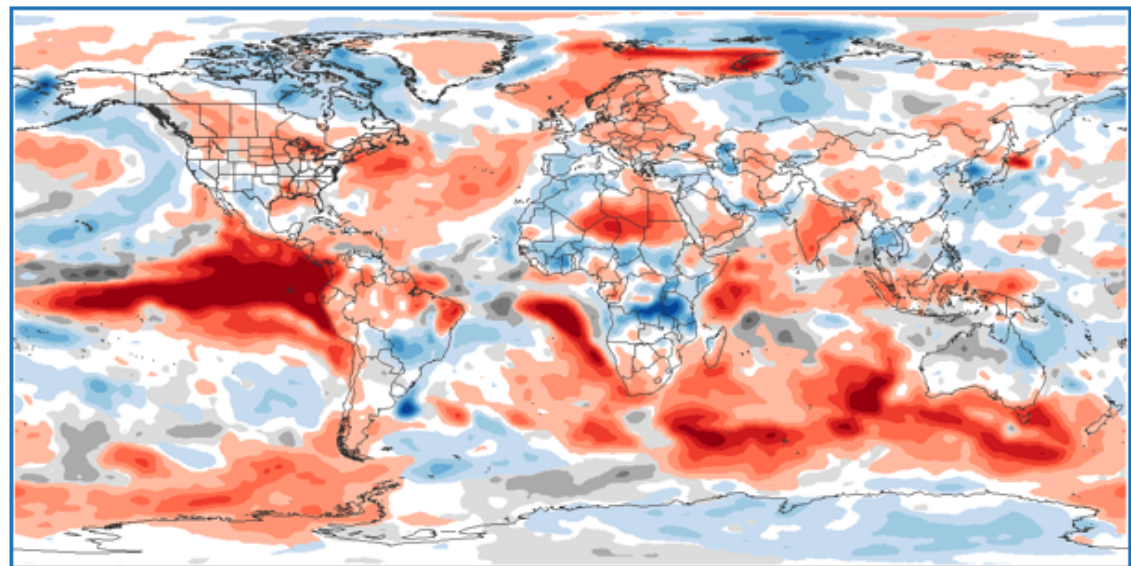


APR 2012						
MAR 2012						
FEB 2012						
JAN 2012						
DEC 2011						
NOV 2011						

CFSv2 Temperature Probability 2000-2009 Climatology Forecast made April 2012 for June 2012

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Model selection

Model	ECMWF	CFSv1	CFSv2
Variable	Temperature	Precipitation	
Forecast	Probability	Anomaly	

Climatology selection ([note](#))

1981-2010 **2001-2010**

Month selection

← Forecast for →

MAY 2012 JUN 2012 JUL 2012 AUG 2012 SEP 2012 OCT 2012

[Reset](#)

↑
Forecast
made

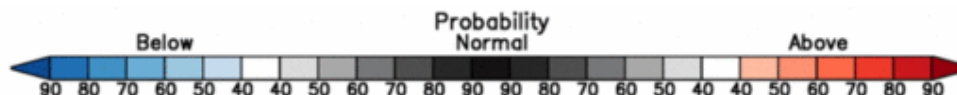
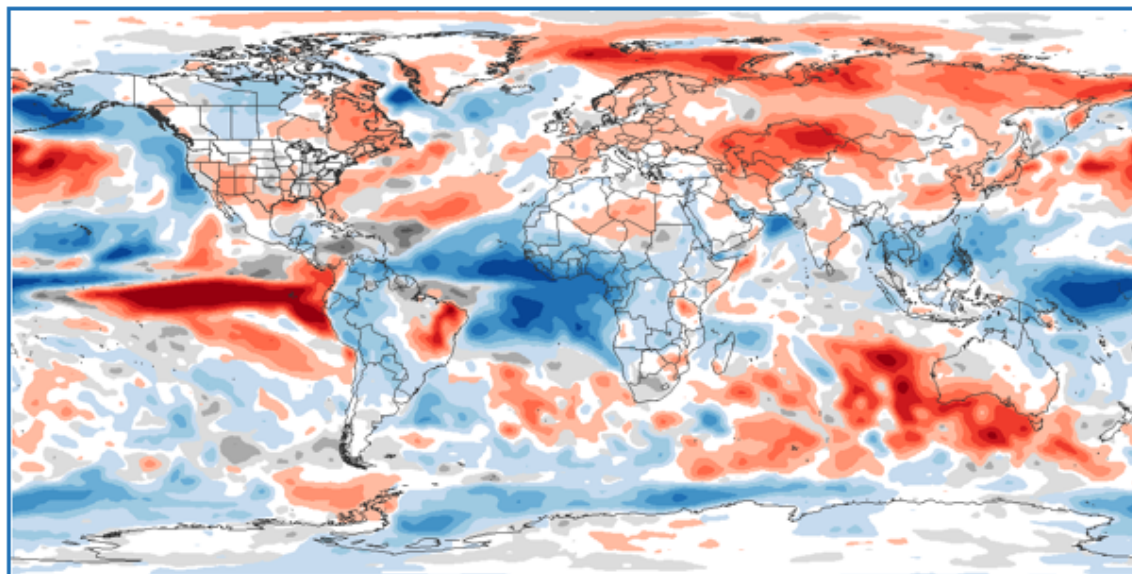


APR 2012
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ECMWF Temperature Probability 2001-2010 Climatology Forecast made April 2012 for June 2012

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Topics for Today

- Seasonal Forecasts—Comparison of Models
- Some Troubling Issues
- Multi-scale Ensemble Forecasts

Acknowledgment

This research was supported in part by NOAA with a Small Business Innovation (SBIR) Phase One Contract



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Goal of Seasonal Prediction

Provide users with reliable probabilities of deviations from average atmospheric and oceanic conditions in the months or seasons ahead so that they can manage risk and take advantage of opportunity.



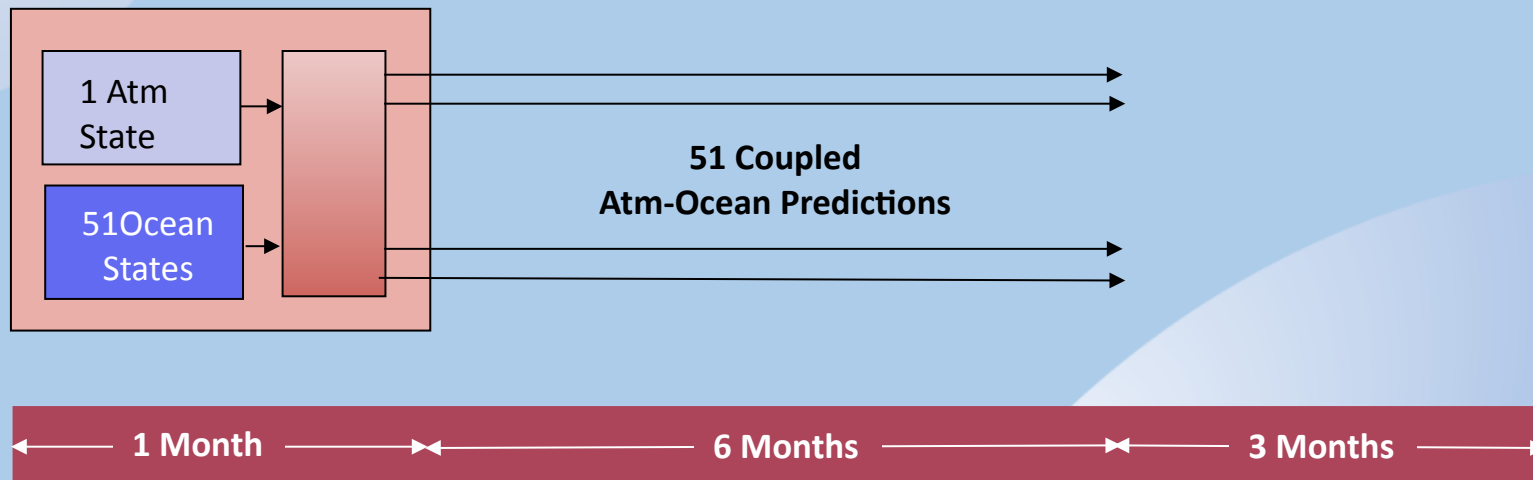
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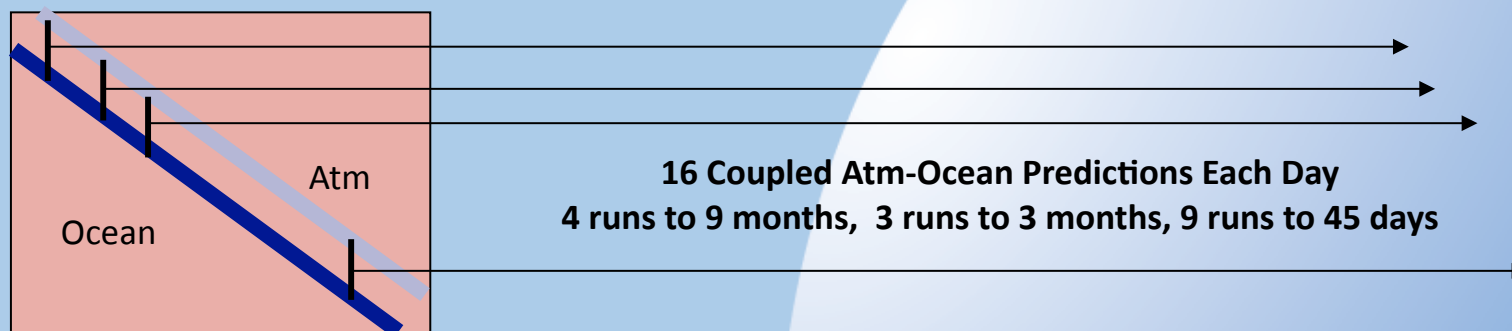
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Two seasonal forecast strategies

ECMWF SPS v4



NCEP CFS v2



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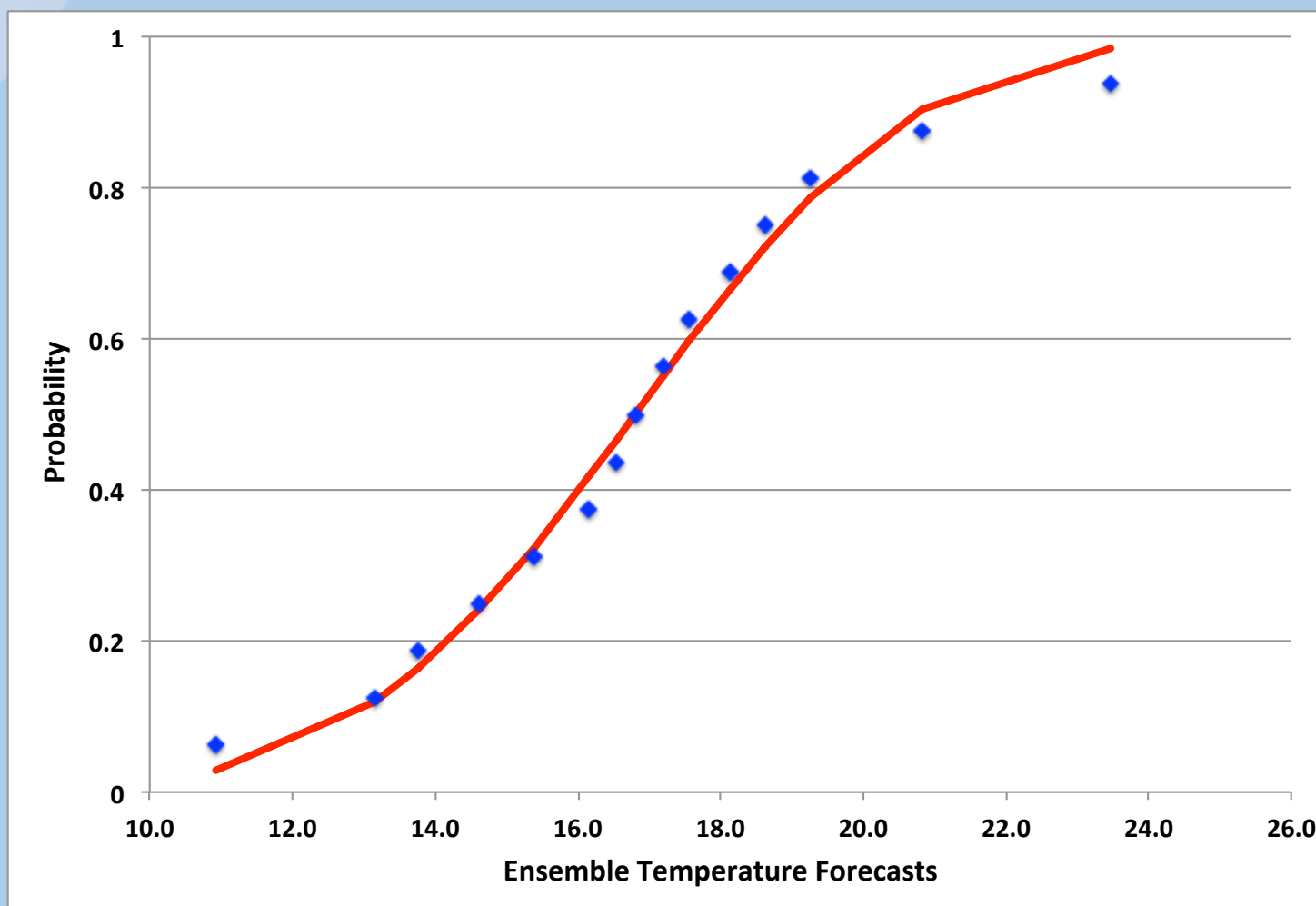
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**An Ensemble
Forecast**

=

**A Forecast of
Probability**



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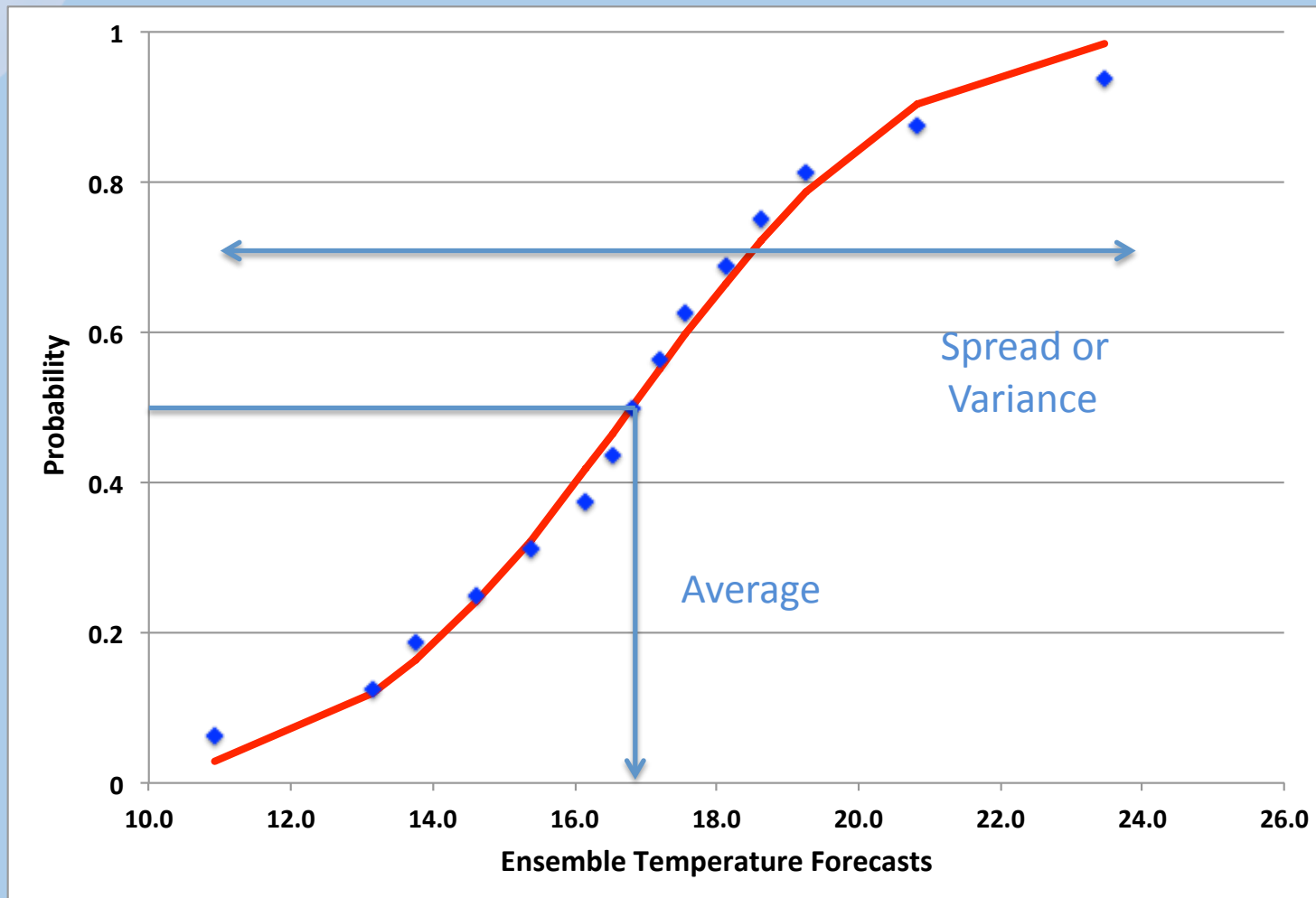
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=

**A Forecast of
Probability**

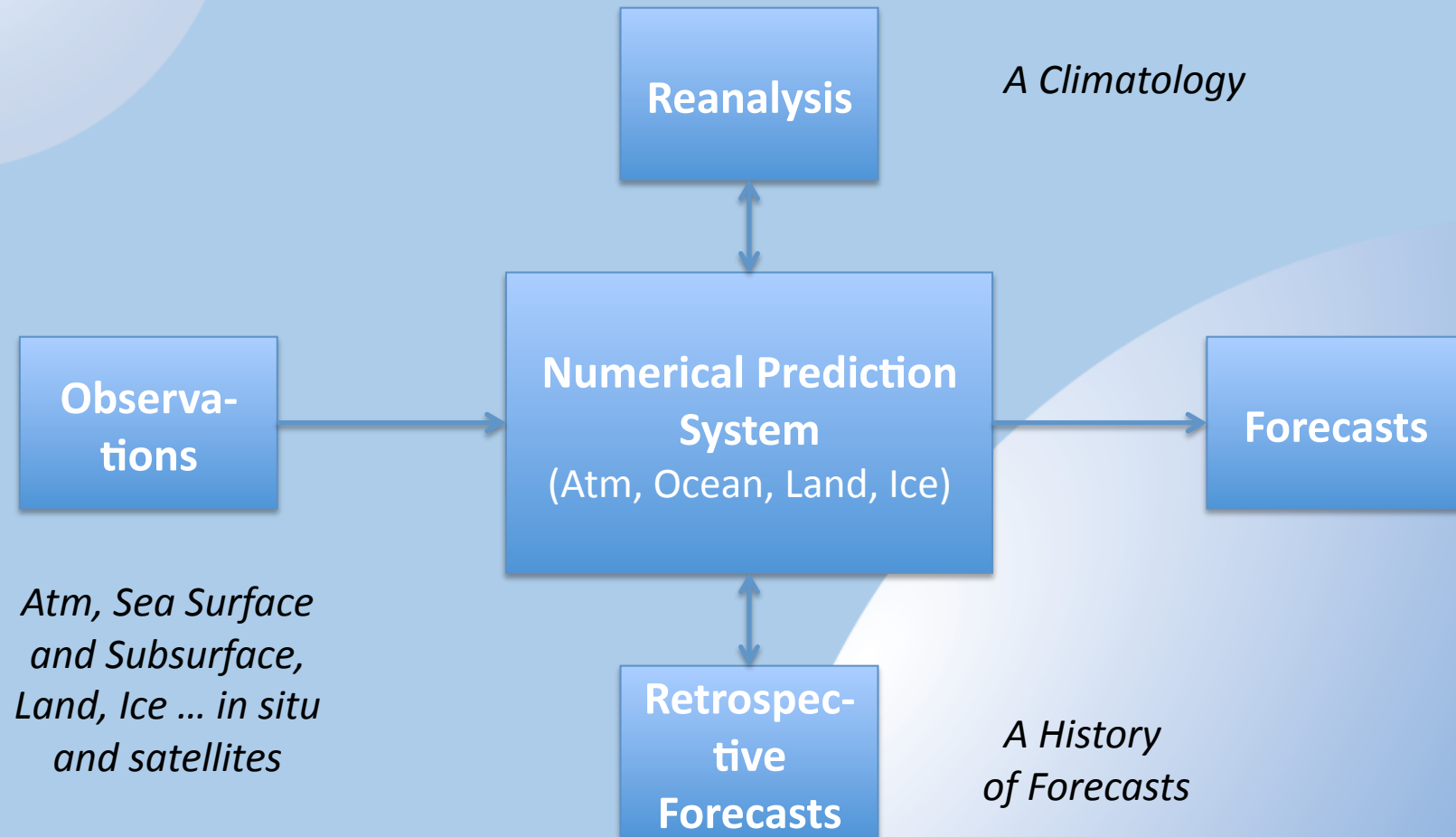


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Components of a Seasonal Prediction System

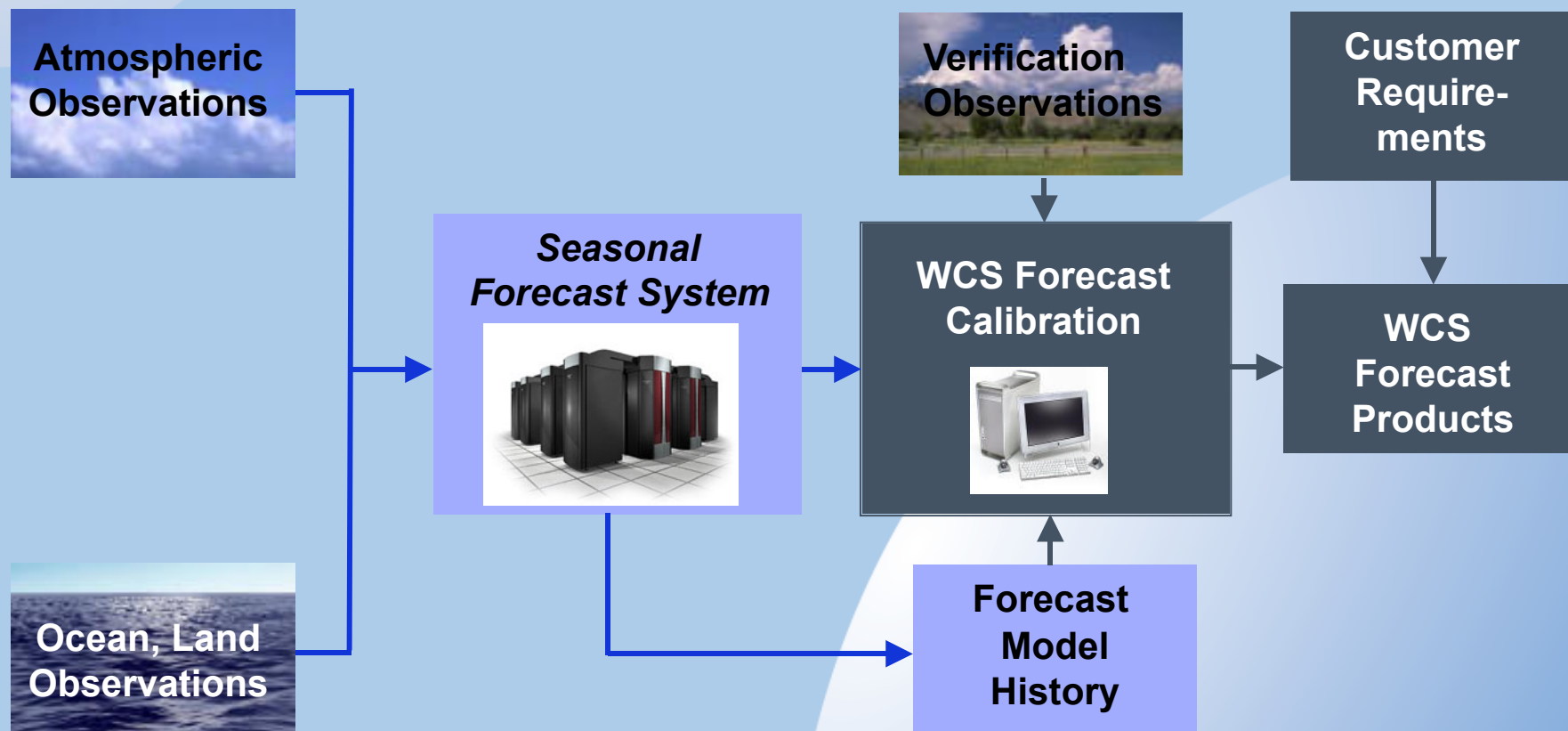


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The WCS Seasonal Prediction System



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A Critical Assumption of Seasonal Prediction

Past errors are a prolog to future errors and can be used to improve future forecasts.

The *reanalysis*, the *retrospective forecasts*, and the *operational forecasts* are equally important components of a *forecast system*.

They should be statistically stationary in order to calibrate the forecasts.

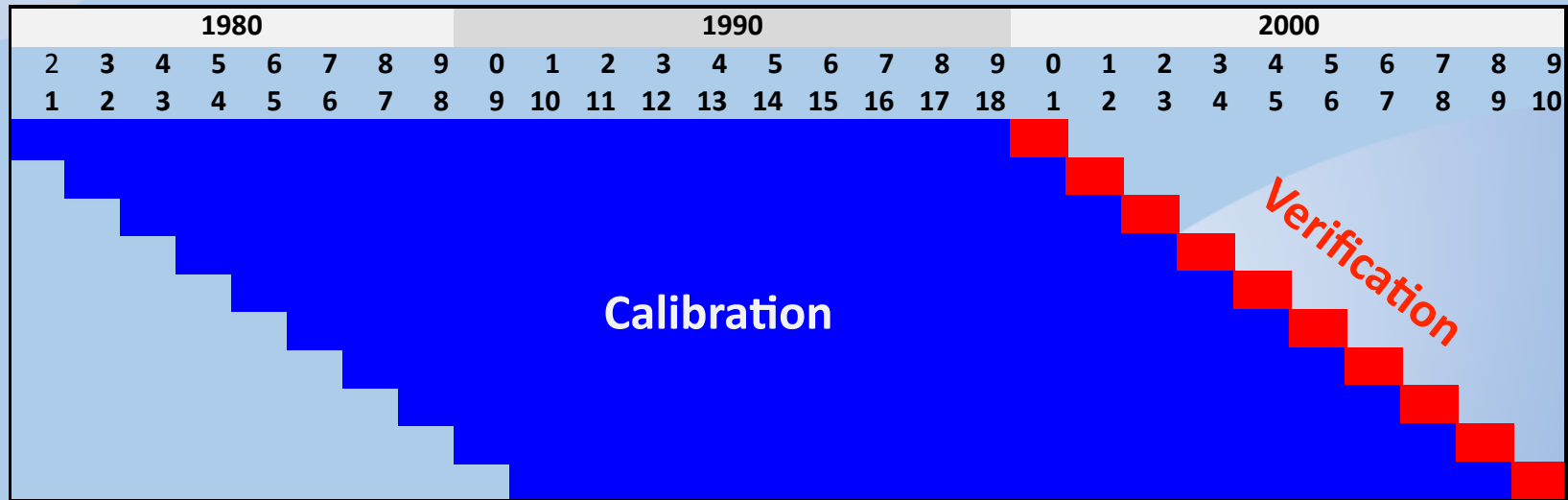


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Seasonal Forecast Calibration and Verification



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Comparing Forecasts To Observations

Forecasts

Observations

	A	N	B	
A	<i>a</i>	<i>b</i>	<i>c</i>	<i>na</i>
N	<i>d</i>	<i>e</i>	<i>f</i>	<i>nn</i>
B	<i>g</i>	<i>h</i>	<i>i</i>	<i>nb</i>
	<i>fa</i>	<i>fn</i>	<i>fb</i>	1

Success Ratio $Sa = a / (a + d + g) = a / fa$

Fraction of events predicted
correctly

Fraction Correct $Fa = a / (a + b + c) = a / na$

Fraction of correct forecasts



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Forecast Skill Summaries

**Fraction Correct
Forecasts**

$$na Fa + nn Fn + nb Fb = F$$

**Fraction Events
Correct**

$$fa Sa + fn Sn + fb Sb = S$$

Perfect Forecasts

$$F_p = S_p = 1$$

Random Forecasts

$$F_r = S_r = 1 / 3$$

Improvement Ratios

$$(F - F_r) / F_r \quad (S - S_r) / S_r$$



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Fraction Correct 2000-2009

October->DJF Variance Scaling

	Below	Normal	Above	All		Below	Normal	Above	All
	North America					Europe			
CFSv2	0.45	0.38	0.45	0.43		0.43	0.46	0.47	0.46
ECMWFv4	0.37	0.39	0.46	0.41		0.26	0.37	0.36	0.34
Multi-model	0.46	0.42	0.47	0.46		0.39	0.41	0.43	0.42
	Global					Tropical Pacific			
CFSv2	0.45	0.39	0.52	0.48		0.74	0.32	0.45	0.48
ECMWFv4	0.4	0.38	0.53	0.45		0.82	0.44	0.7	0.62
Multi-model	0.49	0.41	0.54	0.5		0.83	0.41	0.59	0.56



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Fraction Correct 2000-2009

April->JJA Variance Scaling

	Below	Normal	Above	All		Below	Normal	Above	All
	North America					Europe			
CFSv2	0.39	0.43	0.42	0.42		0.25	0.40	0.47	0.43
ECMWFv4	0.42	0.43	0.42	0.42		0.24	0.41	0.48	0.43
Multi-model	0.41	0.44	0.43	0.43		0.34	0.41	0.48	0.46
	Global					Tropical Pacific			
CFSv2	0.30	0.40	0.51	0.44		0.67	0.35	0.48	0.52
ECMWFv4	0.30	0.40	0.52	0.43		0.61	0.42	0.61	0.54
Multi-model	0.32	0.42	0.52	0.46		0.68	0.45	0.56	0.55



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Success Ratio 2000-2009

October->DJF Variance Scaling

	Below	Normal	Above	All		Below	Normal	Above	All
	North America					Europe			
CFSv2	0.39	0.20	0.67	0.43		0.29	0.31	0.70	0.46
ECMWFv4	0.46	0.27	0.49	0.41		0.20	0.25	0.51	0.34
Multi-model	0.39	0.26	0.68	0.46		0.15	0.29	0.73	0.42
	Global					Tropical Pacific			
CFSv2	0.41	0.24	0.69	0.48		0.33	0.09	0.94	0.48
ECMWFv4	0.37	0.34	0.58	0.45		0.43	0.57	0.81	0.62
Multi-model	0.37	0.33	0.70	0.50		0.33	0.43	0.88	0.56



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Success Ratio 2000-2009

April -> JJA Variance Scaling

	Below	Normal	Above	All		Below	Normal	Above	All
	North America					Europe			
CFSv2	0.27	0.25	0.69	0.42		0.13	0.23	0.71	0.43
ECMWFv4	0.33	0.25	0.66	0.42		0.18	0.26	0.67	0.43
Multi-model	0.25	0.31	0.68	0.43		0.09	0.24	0.78	0.46
	Global					Tropical Pacific			
CFSv2	0.29	0.25	0.65	0.44		0.51	0.03	0.97	0.52
ECMWFv4	0.35	0.38	0.51	0.43		0.53	0.41	0.67	0.54
Multi-model	0.27	0.35	0.62	0.46		0.43	0.30	0.88	0.55



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Relative Performance as Best Model
DJF, JJA — NA, EU, GL, TP — 2000-2009

	Fraction Correct (%)	Success Ratio (%)	Both (%)
CFSv2	12.5	21	17
ECMWFv4	12.5	50	31
Multi- Model	75	29	52



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Return on Hypothetical Plain Vanilla Options

An option on *Above, Normal,* or *Below* costs $\$P$ and pays $\$3P$ for the event that occurs.

For F the fraction of correct forecasts, the rate of return is

$$\begin{aligned} R &= (3 F P - P)/P \\ &= (3 F - 1) \\ &= (F - F_r)/F_r \end{aligned}$$

Multiply by 100 for per cent.

Fraction Correct	Virtual Return (per cent)
0.333	0
0.416	25
0.5	50
0.583	75
0.666	100



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Average Fraction Correct and Average Hypothetical Return

O -> DJF, A->JJA — 2000-2009

WCS Multi-Model

	Global	North America	Europe
Fraction Correct	0.48	0.44	0.44
Return (%)	44	32	32



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Fraction Correct WCS Multi-Model

October -> DJF, 2000-2009

Probability Threshold 50 percent

	Below	Normal	Above	All
GL	59	48	59	57
NA	58	48	53	54
EU	26	39	56	53
TP	91	42	62	59



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Comparing Forecasts To Observations

Number of Observations

Number of
Forecasts

	A	N	B	
A	<i>a</i>	<i>b</i>	<i>c</i>	<i>na</i>
N	<i>d</i>	<i>e</i>	<i>f</i>	<i>nn</i>
B	<i>g</i>	<i>h</i>	<i>h</i>	<i>nb</i>
	<i>fa</i>	<i>fn</i>	<i>fb</i>	<i>1</i>



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Comparing Forecasts To Observations

Number of Observations

	A	N	B	
A	<i>a</i>	<i>b</i>	<i>c</i>	<i>na</i>
N	<i>d</i>	<i>e</i>	<i>f</i>	<i>nn</i>
B	<i>g</i>	<i>h</i>	<i>i</i>	<i>nb</i>
	<i>fa</i>	<i>fn</i>	<i>fb</i>	1

Number of
Forecasts



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WCS Multi-Model Ensemble Forecasts for 2000-2009

	October->DJF			April ->JJA		
	Below	Normal	Above	Below	Normal	Above
GL Forecasts (percent)	20	25	55	18	28	54
GL Obs (percent)	26	31	43	21	33	46
Ratio	0.76	0.81	1.28	0.85	0.84	1.18
NA Forecasts	25	21	55	18	25	57
NA Obs	29	33	38	29	34	36
Ratio	0.84	0.63	1.44	0.62	0.72	1.57
EU Forecasts	10	23	66	5	21	75
EU Obs	28	33	40	19	35	46
Ratio	0.38	0.70	1.68	0.25	0.59	1.63
AU Forecasts (JJA DJF)	19	34	47	15	27	58
AU Obs (JJA DJF)	21	36	43	25	34	42
Ratio	0.92	0.95	1.08	0.62	0.81	1.38
TP Forecasts	12	33	54	17	23	60
TP Obs	32	32	36	27	35	38
Ratio	0.39	1.05	1.49	0.64	0.66	1.58

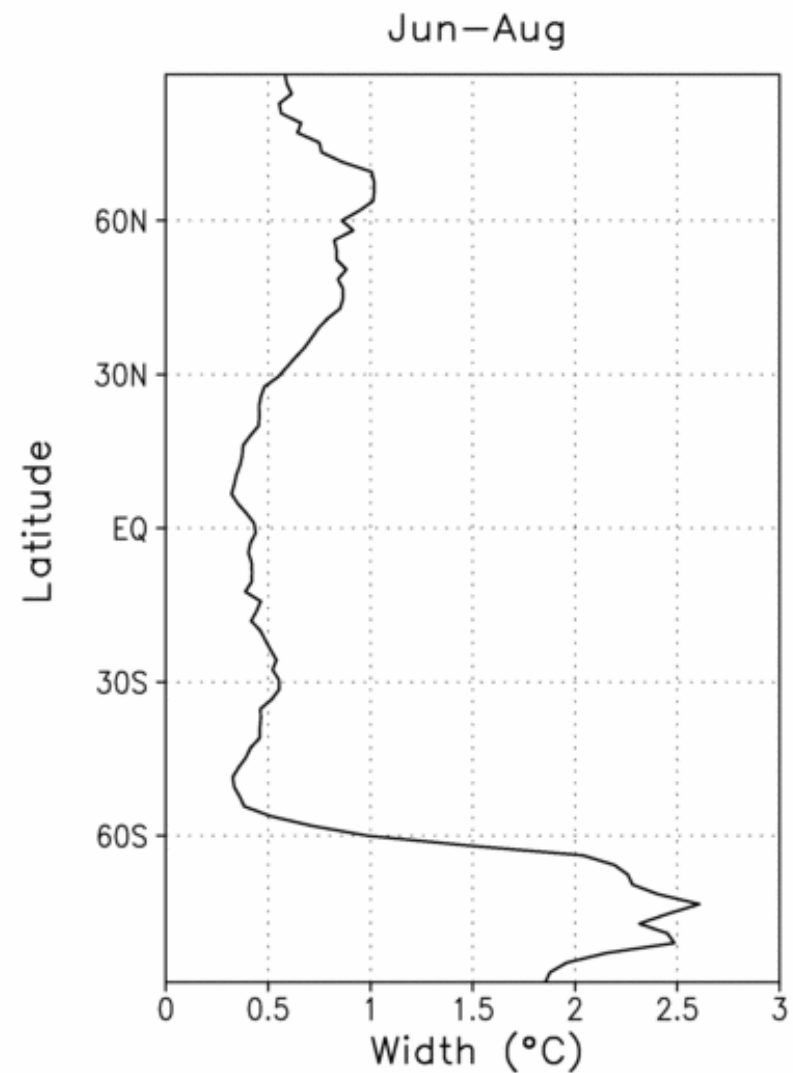
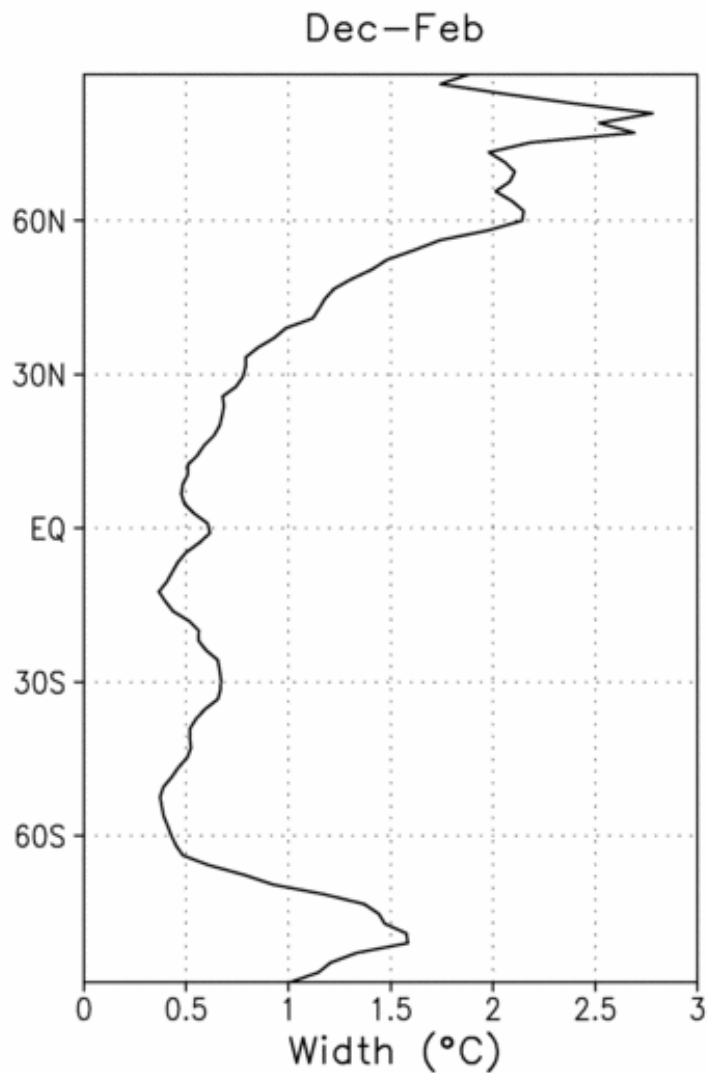


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Width of Near-Normal Temperature Tercile (°C)
Zonal Average 180 °W – 180 °E NCEPGR-2

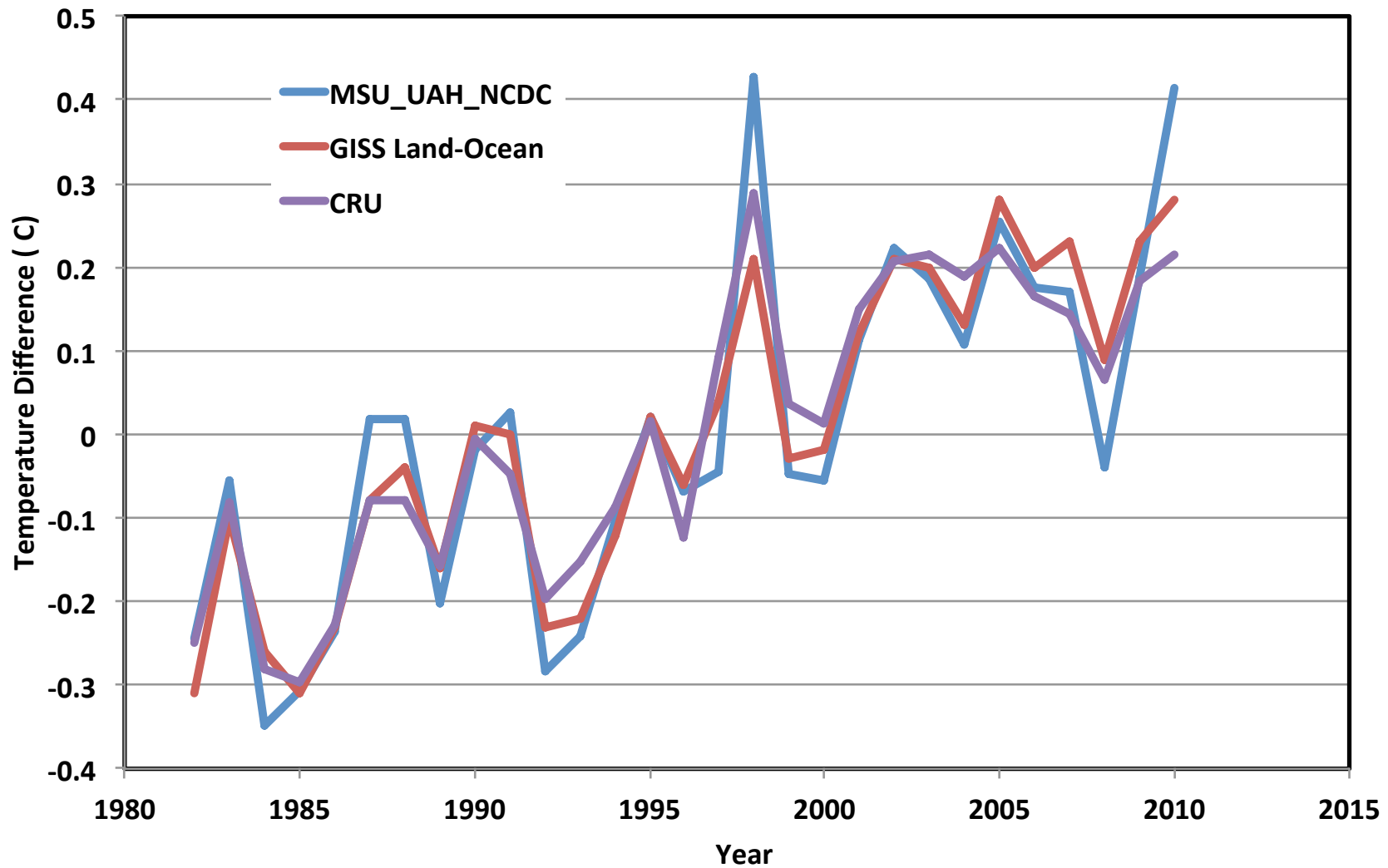


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Global Average Temperature Deviations from 1981-2010 Basis

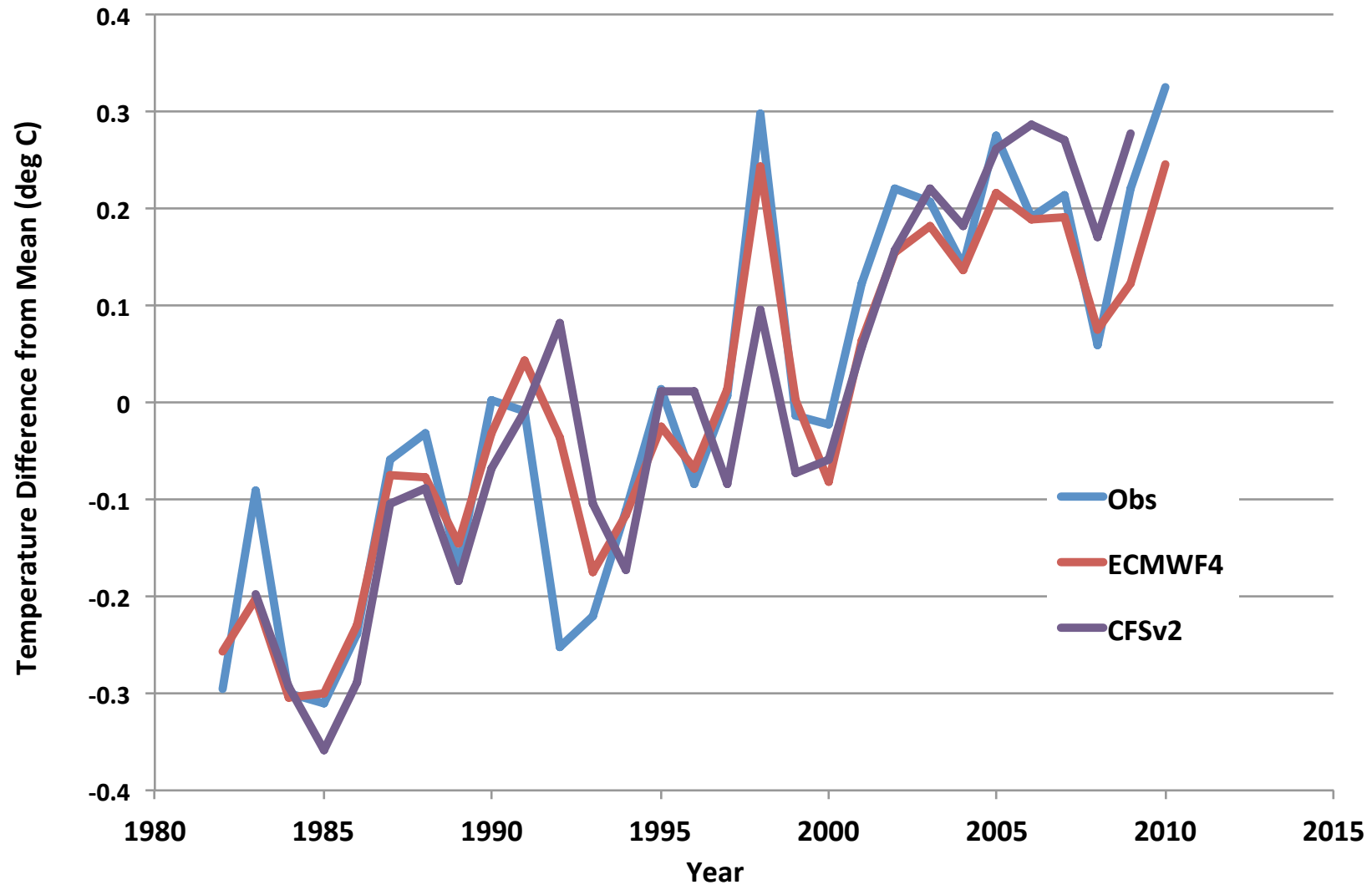


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Comparison of Global Average Temperature Trends

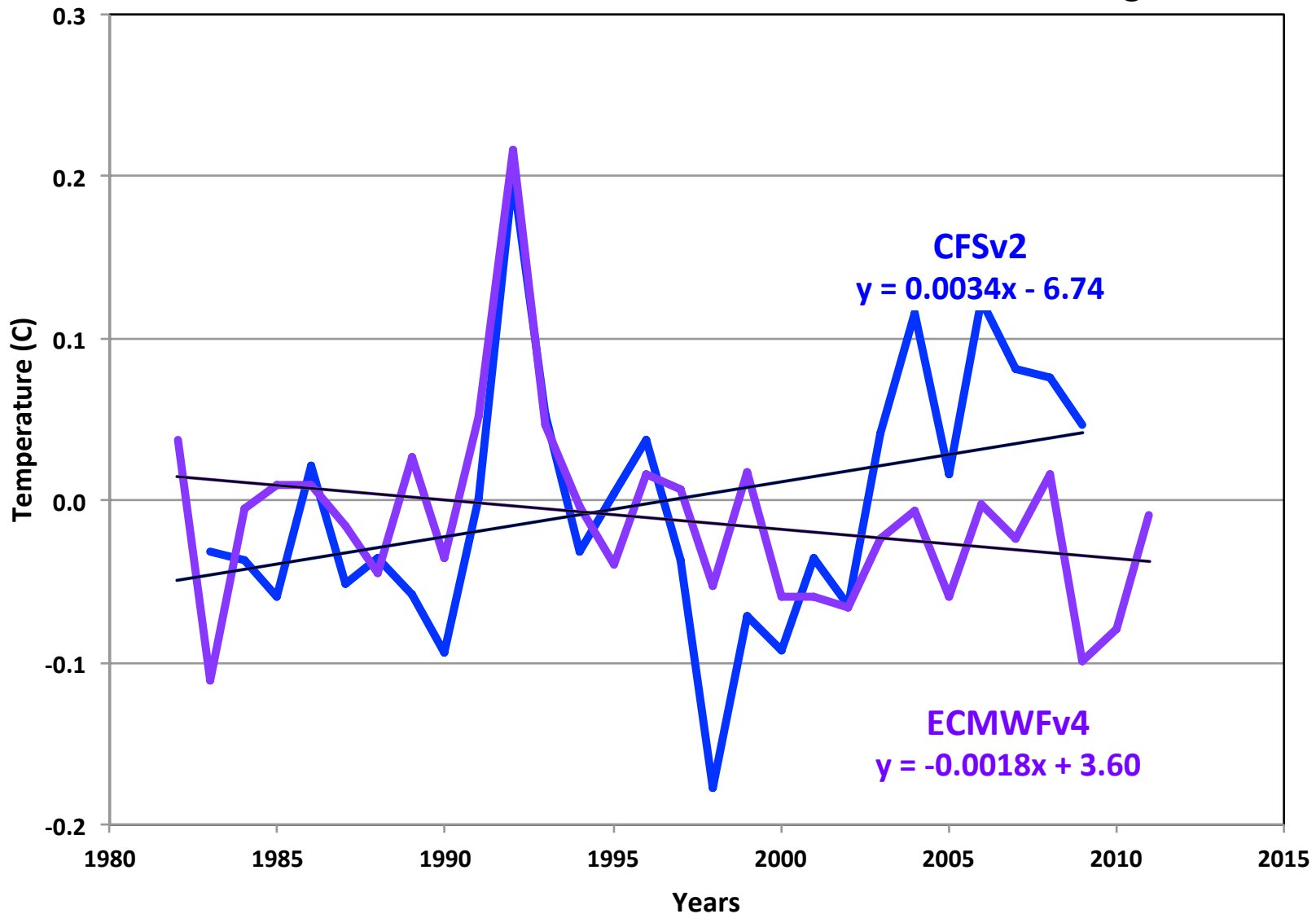


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Difference of Predicted and Observed Global Annual Averages

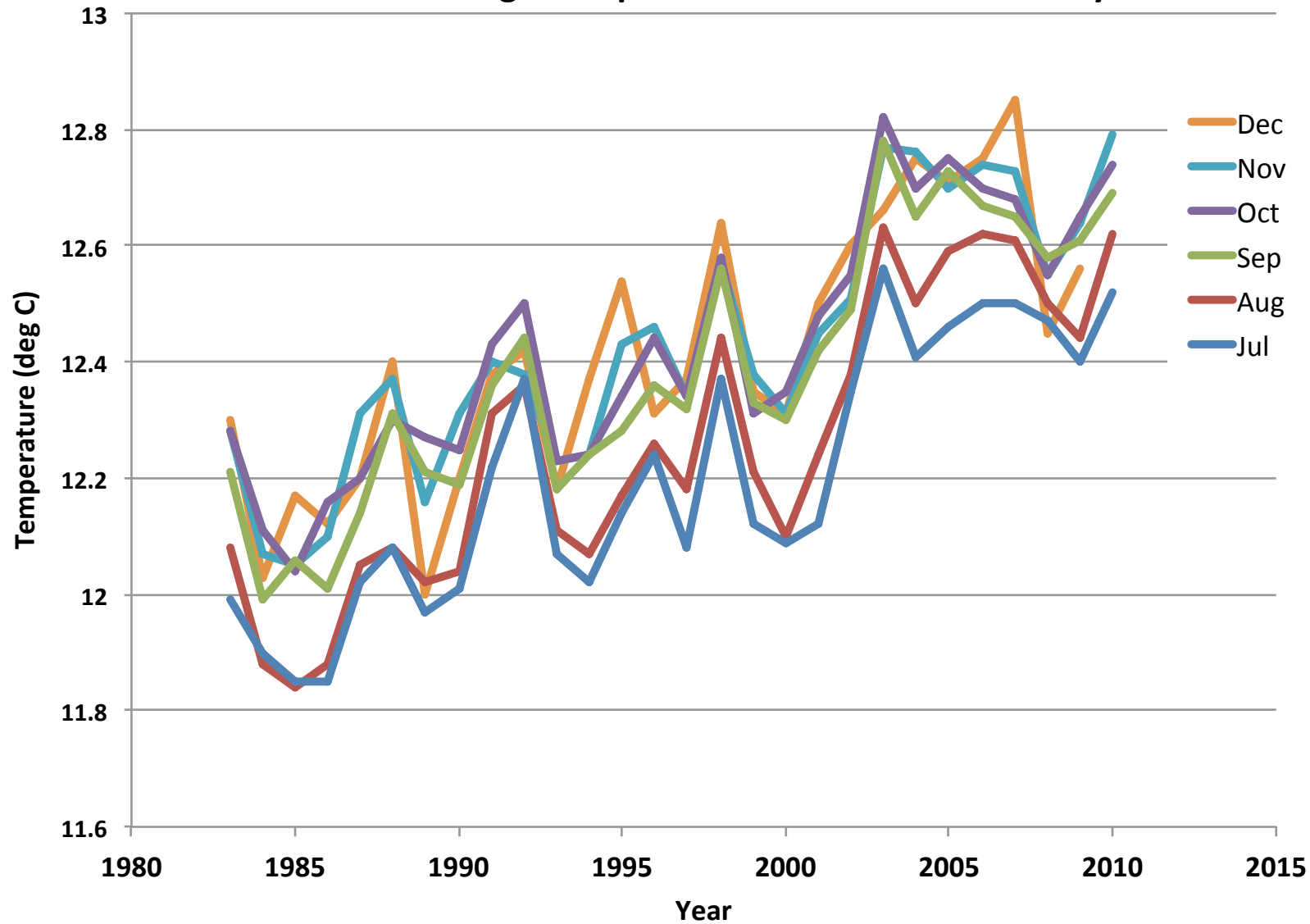


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CFSv2 Global Average Temperature Forecasts for January 1983-2010

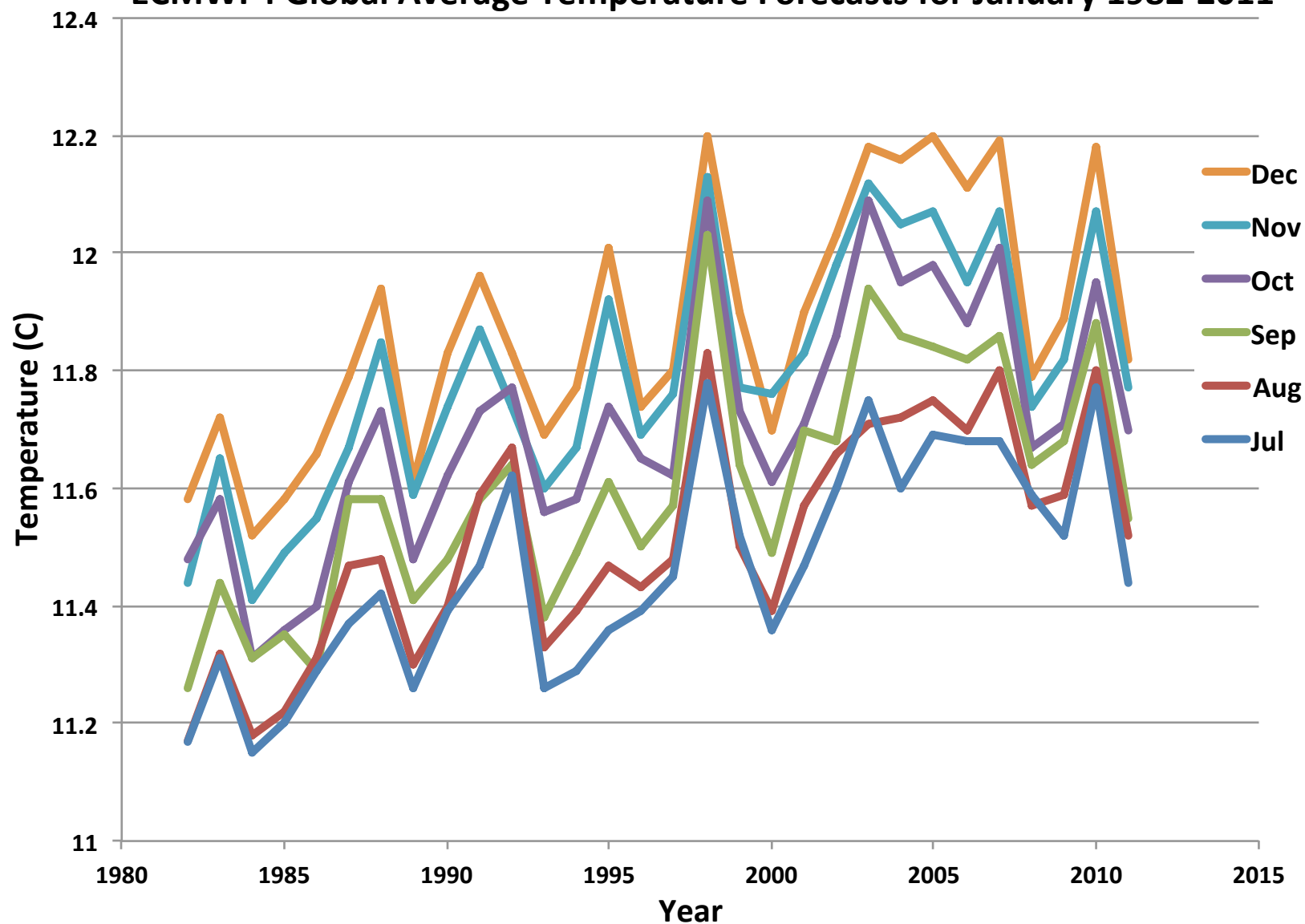


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ECMWF4 Global Average Temperature Forecasts for January 1982-2011

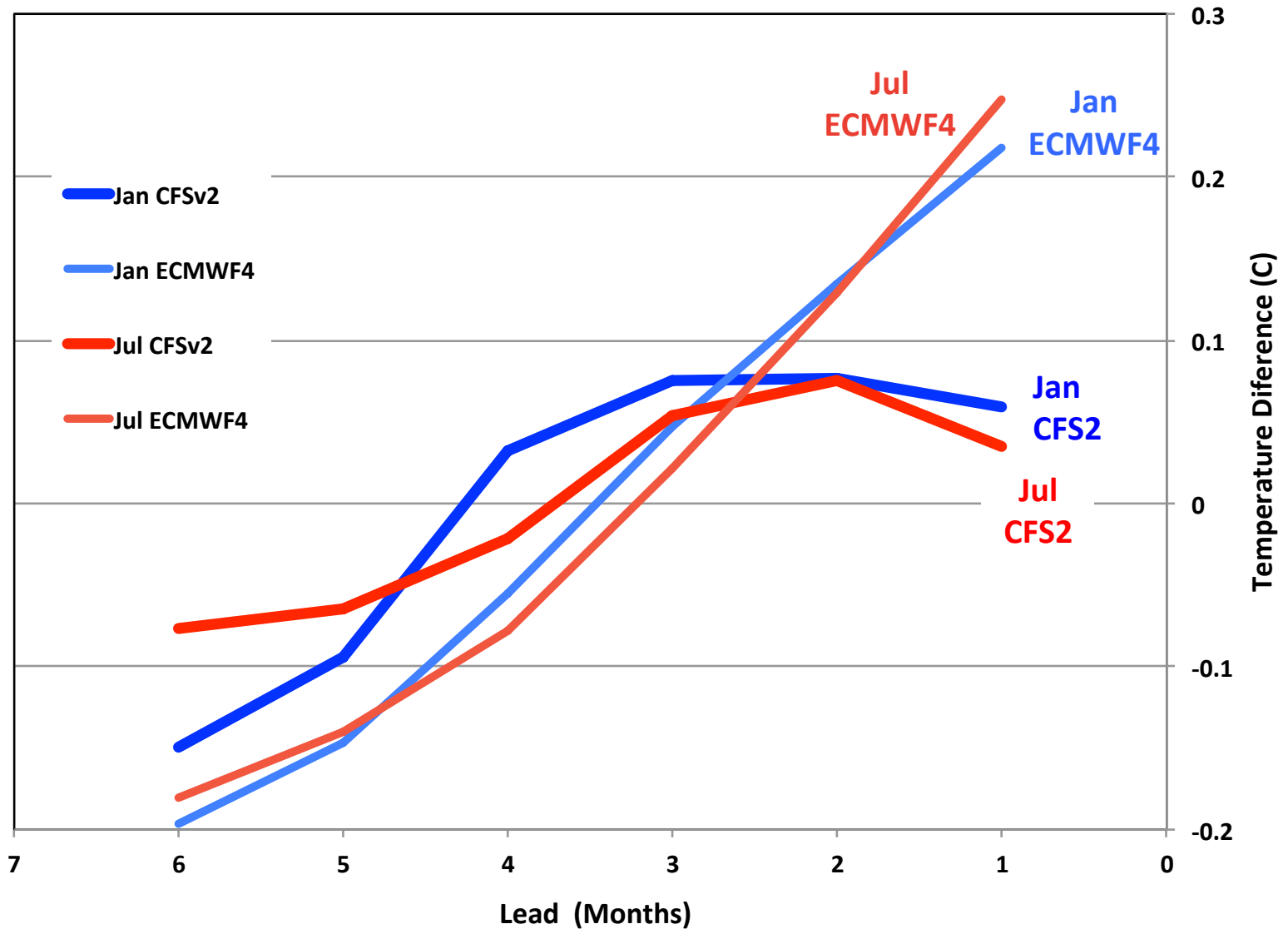


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Difference from Average Over 6 Leads



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It seems that CFSv2 is warming more rapidly than the observations; ECMWF is not warming as fast.

A first try at reconciling trends in the same way we reconcile averages by removing bias was not successful.

The standard statistical advice is to separate long-term trends and short-term variations and treat them independently.

Perhaps we should follow that advice.



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WCS Multi-scale Ensemble Prediction System

The reliability of forecasts can be improved by averaging over increasing periods as the lead time increases ...

a day for forecasts days ahead

a week for forecasts weeks ahead

a season for forecasts seasons ahead

Multi-scale probabilistic forecasts can be constructed by using increasing average times as lead times increase

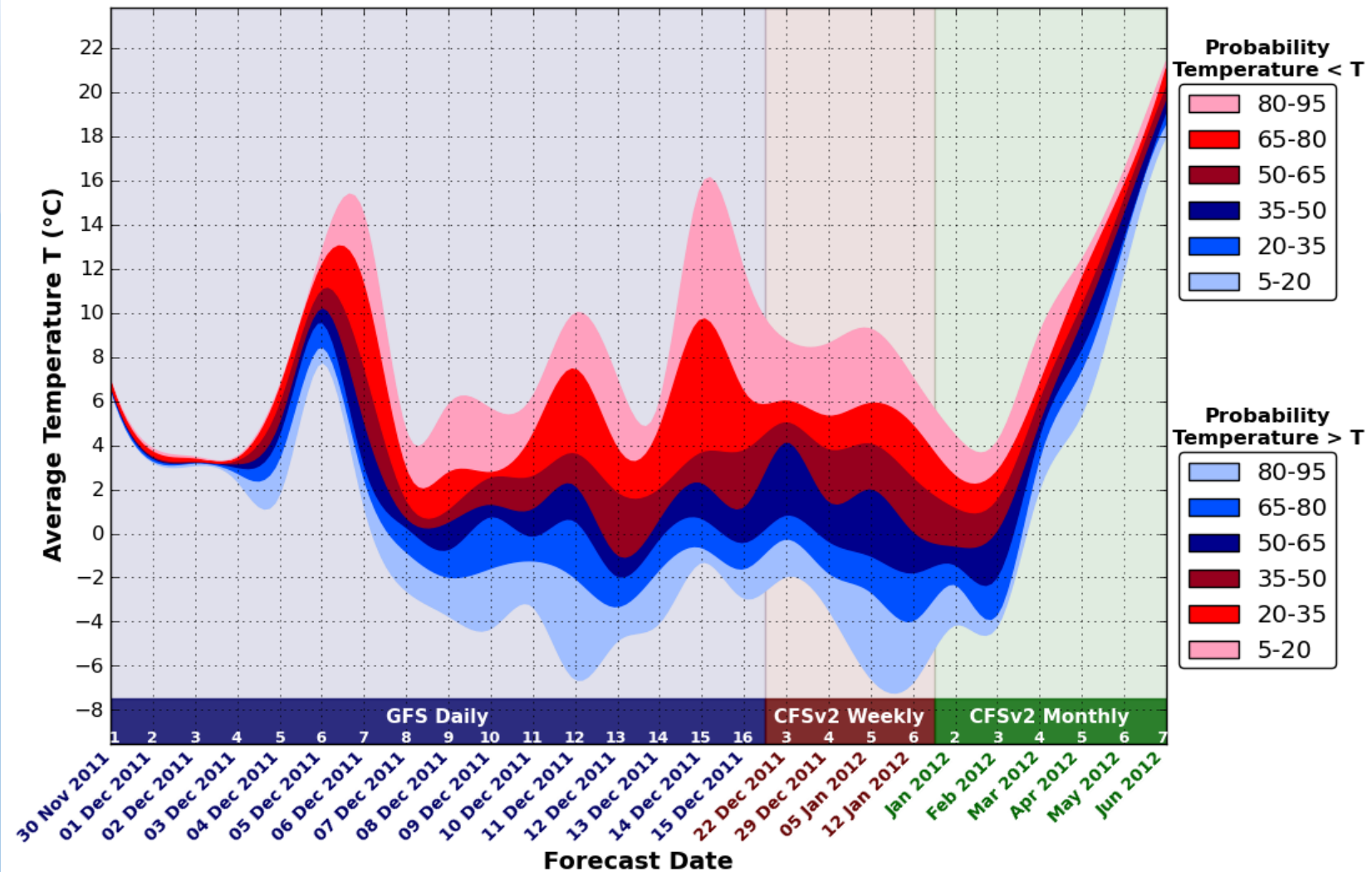


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Washington DC 2m Temperature Probabilities WCS Multiscale Ensemble Prediction System (GFS + CFSv2)

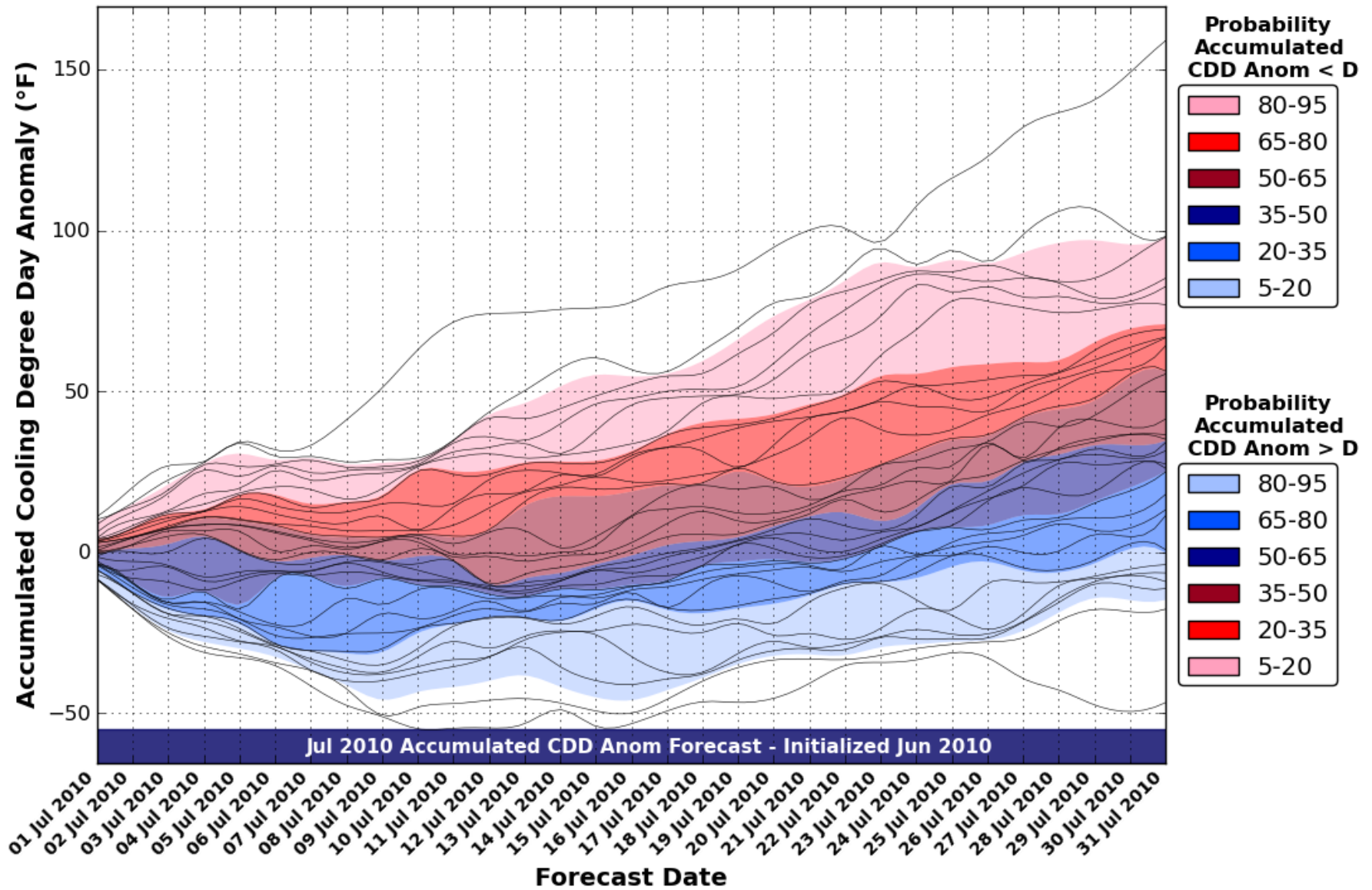


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Washington DC Cooling Degree Day Anomaly Probabilities WCS SIDSS (CFSv2)



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Summary

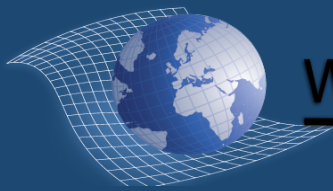
- The calibrated seasonal probability forecasts demonstrate sufficient skill to be of value in the energy and other industries for mitigation of risk and identification of opportunity;
- The WCS multi-model is somewhat better on average than either CFSv2 and ECMWFv4 used alone and offers hypothetical rates of return of greater than 30 per cent.
- Forecast performance will likely be improved with improved management of the effects of climate trends; perhaps we should rethink our modeling strategy.
- New methods of presenting probabilities will assist users to make more effective decisions.



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Transition to Energy Variables

Energy impact variables are often non-linear functions of atmospheric variables

$$\text{Heating Degree Days} = \text{Max}[T_0 - T, 0]$$

$$\text{Available Wind Energy} \approx w(V) V^3$$

Probability distributions for these variables must be computed from the six-hourly data of the seasonal forecast ensembles and then examined or averaged as required for decision support.

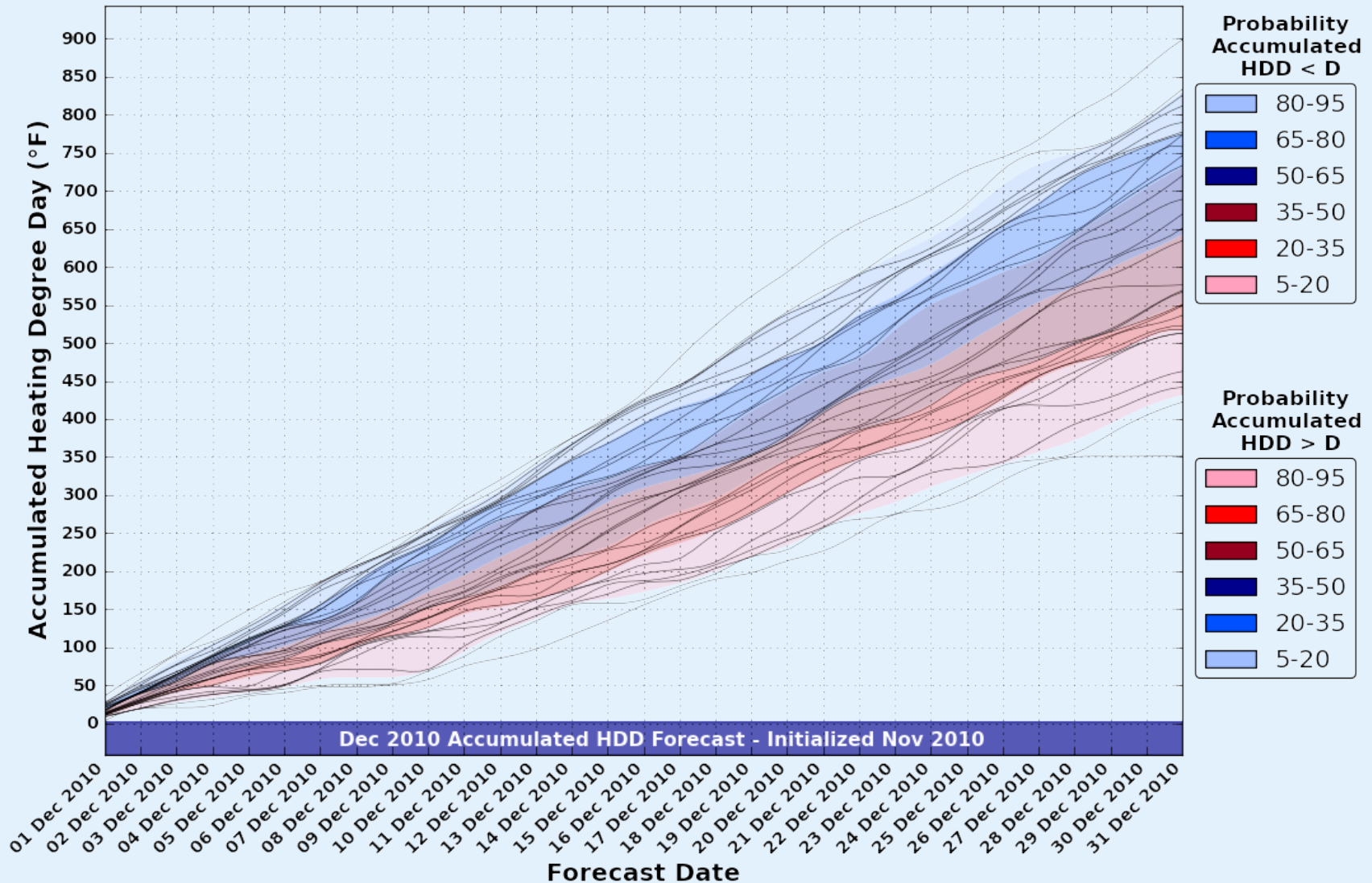


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Atlanta Heating Degree Day Probabilities WCS SIDSS (CFSv2)



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